Radar
Industrial Base

Radar Industrial Base Study

Office of DUSD (Industrial Affairs)

May 3, 2001

Radar Industrial Base

Study Parameters

- Key Goals:
  - Identify radar technology trends
  - Evaluate DoD demand for radar products over the next decade
  - Determine whether there is sufficient demand to support multiple radar suppliers
  - Competition Issues:
    - Is there sufficient competition (i.e., multiple suppliers with capabilities and market presence to credibly compete)?
    - What is the extent of vertical integration into radar subtier supplies?
- Scope of Study: Product Coverage
  - Air and missile defense radars, plus other relevant applications* .
    - All frequency bands, architectures, platform types.
  - Both domestic and foreign sales.

* In the slides that follow, “radar” will refer to systems within this scope. Other applications were included when they were deemed to support air and missile defense radar design and/or production base.

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Radar Technology & Industrial Trends

Radar Industrial Base

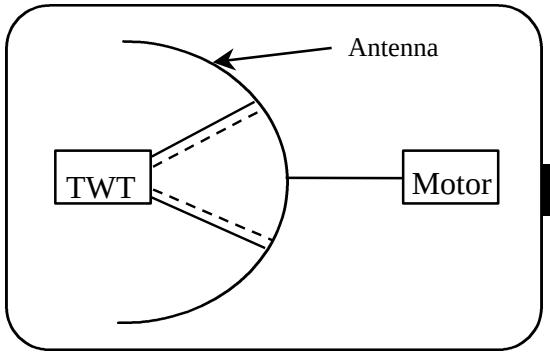
Information Sources

- Information was obtained from multiple sources including:
  - DoD: Inputs collected by Services and Agencies from their program offices.
  - DACIS: Defense/Aerospace Contracts Database compiled by InfoBase Publishers, Inc.
  - Industry: Discussions with defense radar contractor personnel.
  - Open Sources: Press releases, internet, etc.

Radar Industrial Base

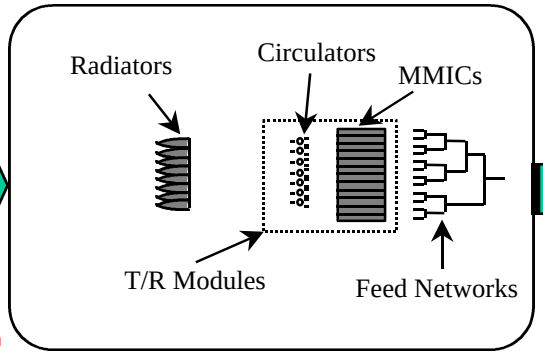
Radar Performance Evolution

Past
Mechanically Steered Antenna (MSA)



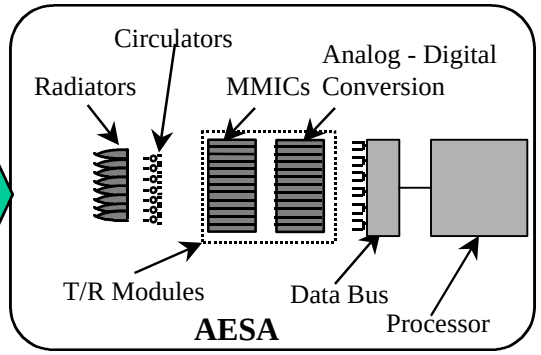
- Single function
- Limited interference (clutter & jamming) rejection

Current
Active Electronically Steered Antenna (AESA)



- ✓ Multi function
- ✓ Improved interference rejection
- ✓ High sensitivity (small targets)
- ✓ Target discrimination)
- ✓ Low observability
- ✓ High reliability

Future
Digital Radar

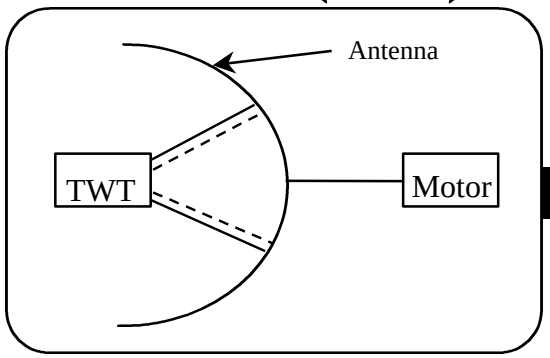


- ✓ Significantly improved interference rejection
- ✓ Higher sensitivity
- ✓ Improved discrimination
- ✓ Conformal antenna (Smart skins)
  - –Improved low observability and high field of regard

Radar Industrial Base

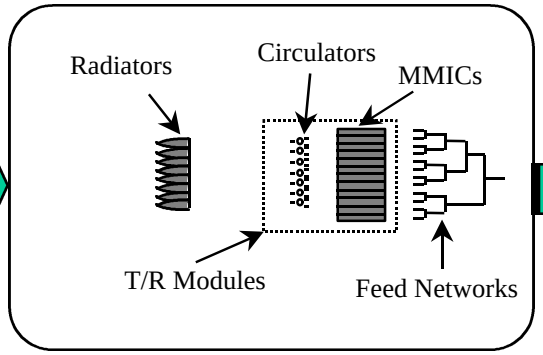
Radar Technology Evolution

Past
Mechanically Steered Antenna (MSA)



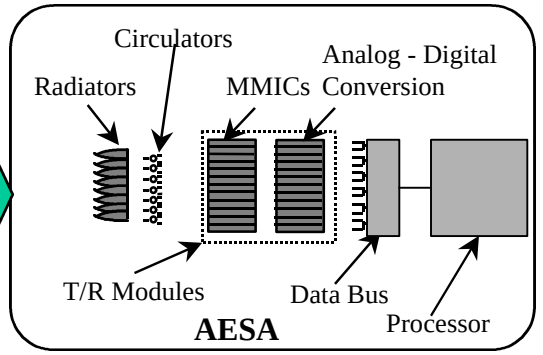
- Reflector antenna
- Transmitter tube
- 1-3 fixed channel analog receiver
- Simple waveform set
- Low noise RF
- Standard A/D and D/A conversion

Current
Active Electronically Steered Antenna (AESA)



- Flat antenna array
- Hi-power MMIC
- 4-18 fixed channel analog receiver
- Complex waveform set
- Very low noise RF
- High speed large dynamic range A/D and D/A conversion

Future
Digital Radar



- Conformal antenna array
- Very high power MMIC
- Variable channel digital receiver
- Direct digital synthesis waveforms
- Extremely low noise RF
- Module level high speed large dynamic range A/D & D/A conversion

Radar Industrial Base

Radar Development Programs

Program	High Band?	AESA?	Lockheed Martin	Northrop Grumman	Raytheon
APG-77 (F-22)	✓ (X)	✓		✓	
APG-79 (F/A-18)	✓ (X)	✓			✓
F-16 Block 60(UAE)	✓ (X)	✓		✓	
JSF	✓ (X)	✓		?✓	?✓
MP-RTIP	✓ (X)	✓		✓	✓
ASTOR(UK)	✓ (X)	✓			✓
MEADS MFCR	✓ (X)	✓	✓		
THAAD Radar	✓ (X)	✓			✓
XBR	✓ (X)	✓			✓
SPY-3	✓ (X)	✓			✓
HPD-X	✓ (X)	✓			✓
SS SPY	(S)	✓	✓		
Wedgetail(Aus)	(L)	✓		✓	
VSR	(L)	✓	?✓		?✓
MEADS SR	(UHF)	✓	✓		
DASR	(L)				✓

High Band Technology Low Band Technology May Be Either Technology

(For details, see “High/Low Band Partitioning” chart)

Radar Industrial Base

Radar Applications Share Many Common Elements

	Radar Platform Applications			
Radar Elements	Air/Land/Sea	Air Only	Land Only	Sea Only
Signal Processing	- Target identification & discrimination - Clutter suppression - Jammer Suppression - Radar data conversion	- Moving Platform-target - Moving clutter - Air/ground intelligence - Ground mapping	- Site specific clutter	- Multiple array control & processing - Wave form softening & adaptive wave forms - Multipath & ducting
Hardware Design	- Low phase noise exciter - T/R modules - AESA power/cooling - Power conversion	- Volume, power, cooling constraints - Low observable antenna	Large array	Large array
Manufacturing	- System assembly, integration & test - Array calibration & test - Built-in-test - RF subsystem assembly & test	- High integrity circulators - Array structure; precision machinery - Air environment	Transportability environment	Sea environment

Elements of radar design and architecture are common across host platform types to varying degrees. AESA technology increases that commonality.

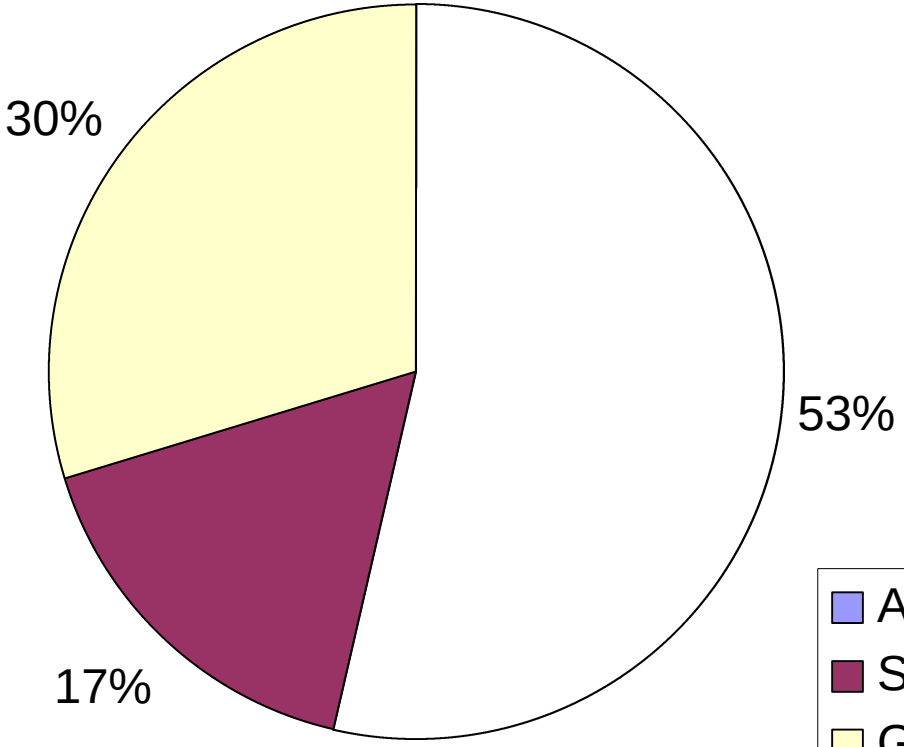
Radar Industrial Base

Demand

Radar Industrial Base

Radar Demand by Platform Type (FY'00 - '07)

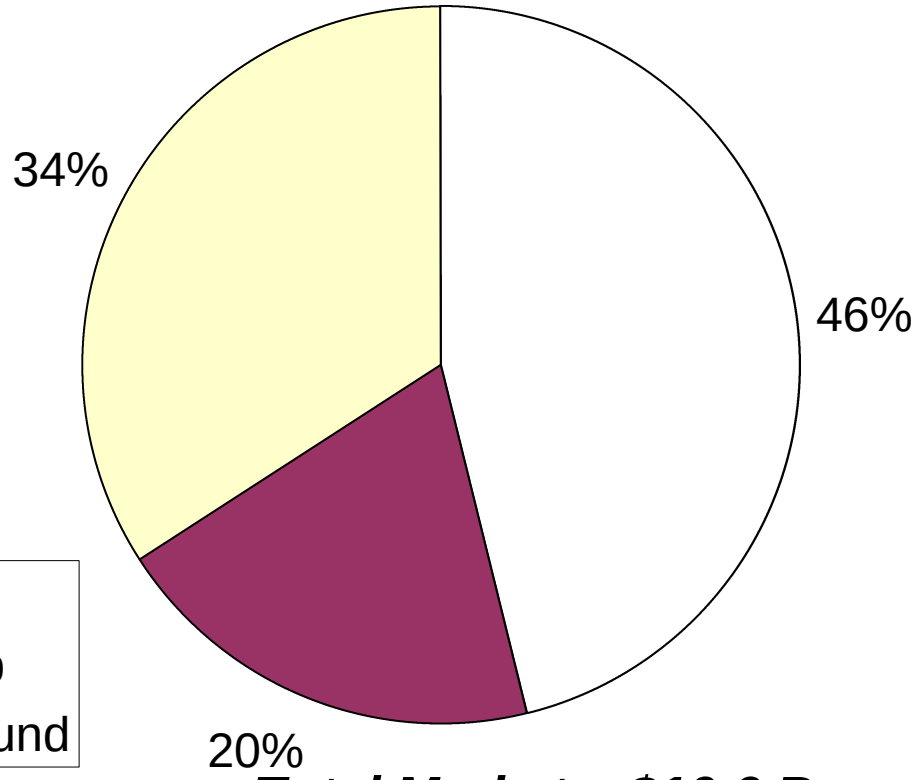
Production



Total Market = $18.8 B

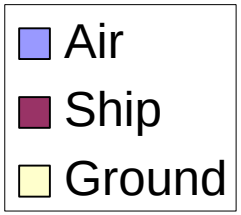
($18.3 B awarded)

R & D



Total Market = $10.6 B

($7.3 B awarded)

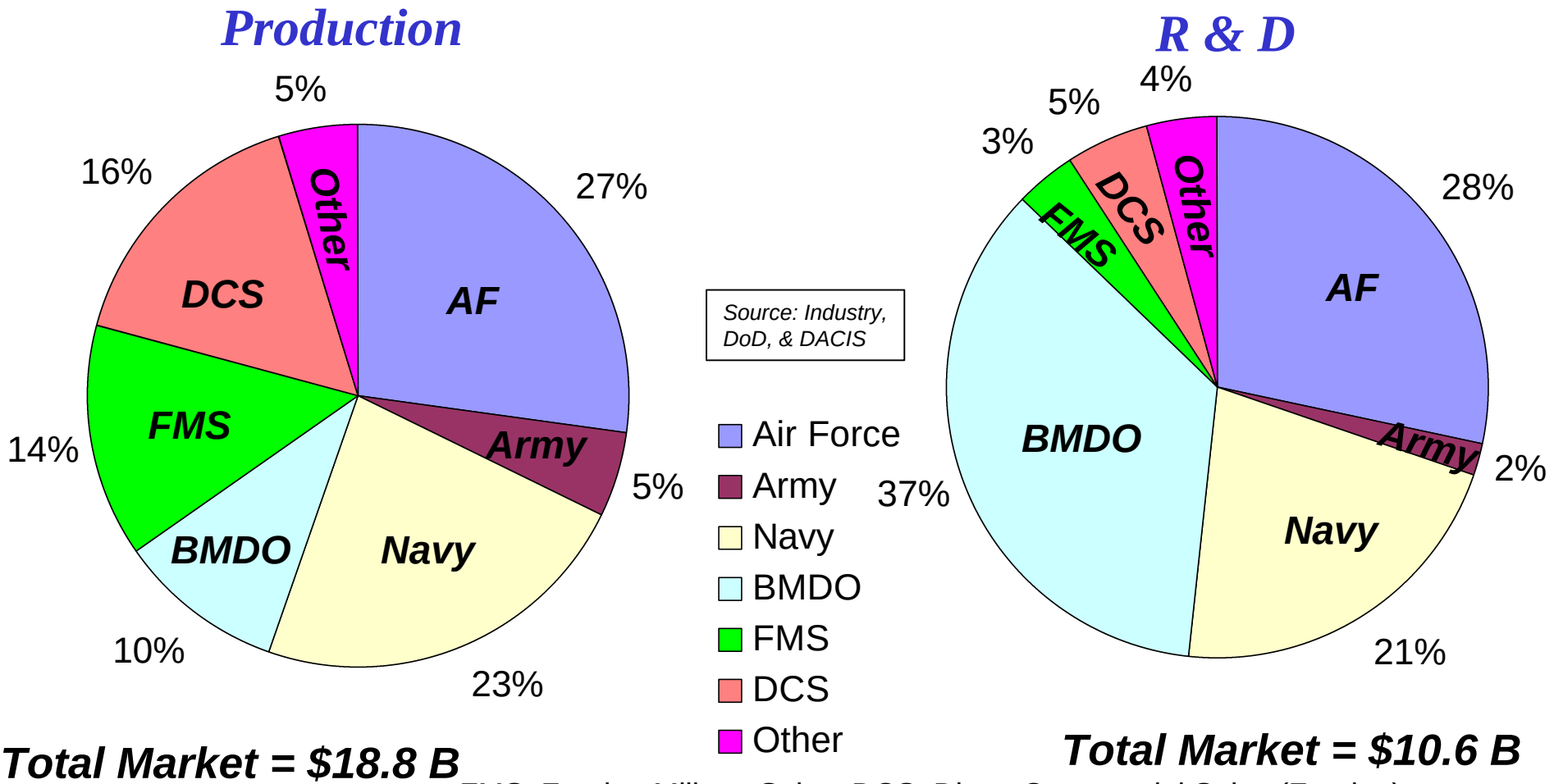


Average Annual Production:	$2.4 B
Average Annual R&D:	$1.4 B

Source: DoD & DACIS

Radar Industrial Base

Radar Demand by Funding Source (FY'00 - '07)



Total Market = $18.8 B

Total Market = $10.6 B

FMS: Foreign Military Sales, DCS: Direct Commercial Sales (Foreign)

Foreign sales accounts for 30% of production, but less than 10% of R&D. BMDO, Air Force and Navy drive R&D funding.

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Competition Issues

Radar Industrial Base

US Radar Manufacturers

- **Three large manufacturers** capture 96%* of production and 99%* R&D.
  - Lockheed Martin:
    - Air & ground: Syracuse, NY
    - Ship: Moorestown, NJ (mostly SPY-1)
    - Goodyear, AZ (SARs)
  - Northrop Grumman:
    - Most production in Baltimore (mostly airborne)
    - Smaller operations in Norwalk, CT (JSTARS) and Melville, NY (ship)
  - Raytheon: Current activities:
    - Large land and ship: Boston area; production in Andover, MA
    - Air and small land: Fullerton, El Segundo, CA (production in Forest, MS); McKinney, TX (SARs)
    - Air Traffic Control: Waterloo, ONT
- **Small manufacturers** producing niche products.
  - Telephonics: Farmdale, NY (SARs)
  - ITT Gilfillan: Van Nuys, CA (ship and ATC)
  - etc.

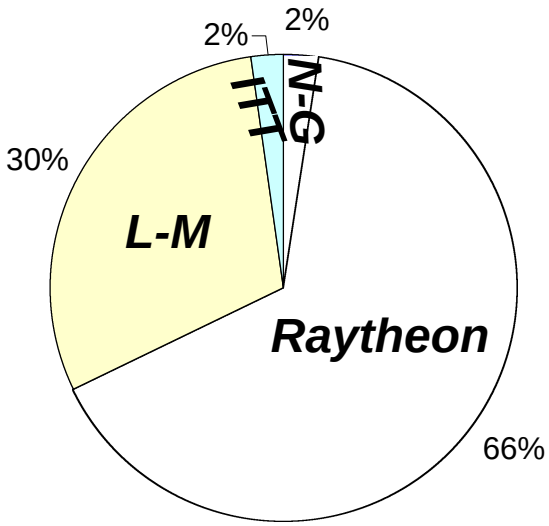
Source: DoD & DACIS

* Based on FY'00-'07 data

Radar Industrial Base

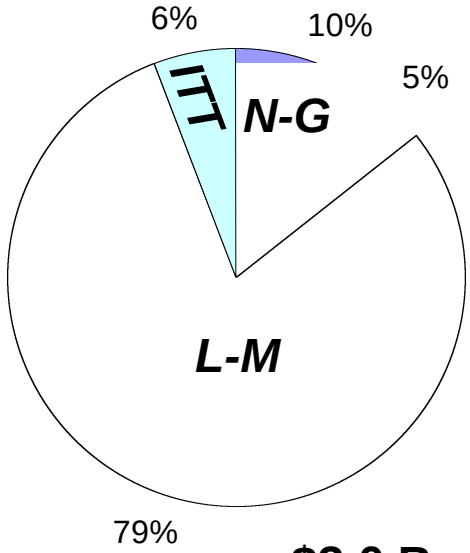
Radar Production by Company (FY'00 - '07)

Land-based



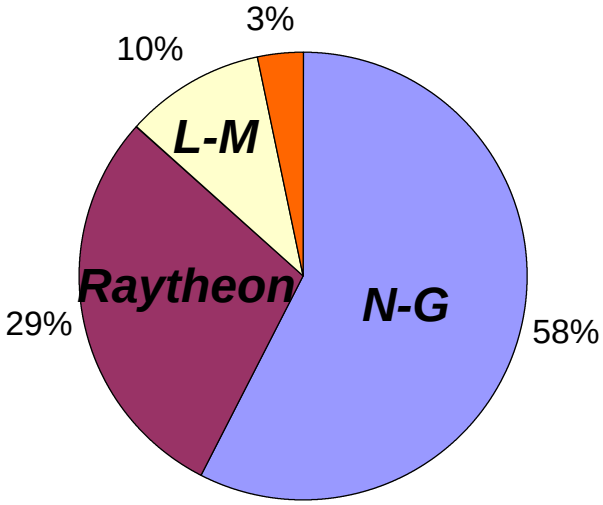
$5.6 B

Shipborne



$3.0 B

Airborne



$9.7 B

Total Market = $18.8 B
($18.3 B awarded)

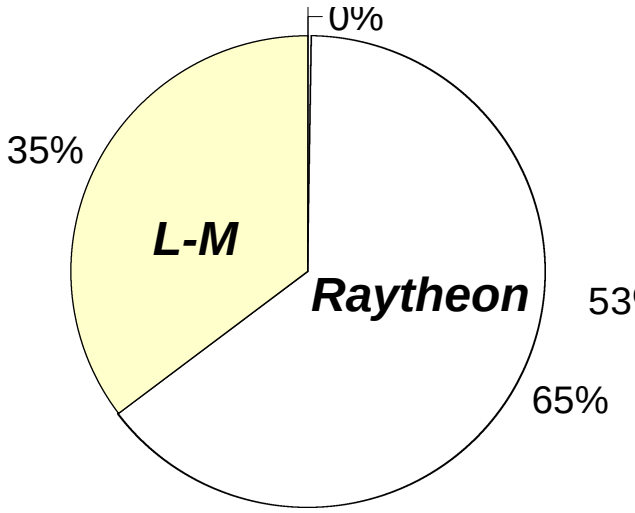
Source: Industry, DoD, & DACIS

Each of the major suppliers is market lead for one platform type. Airborne is 53% of the market.

Radar Industrial Base

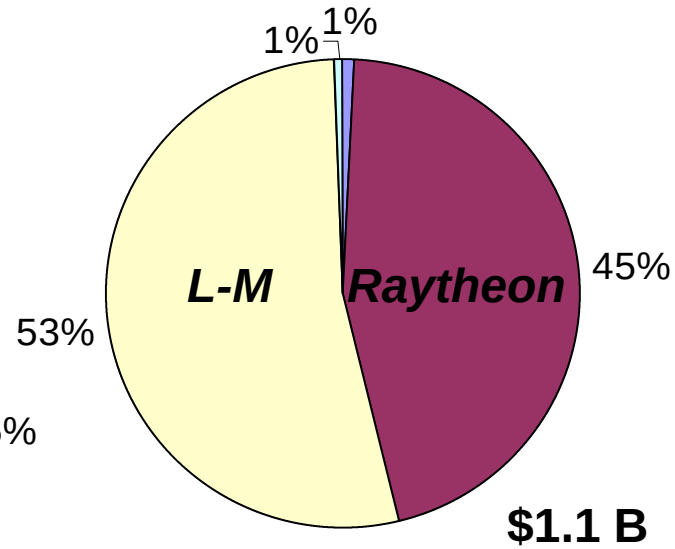
Radar R&D by Company (FY'00 - '07)

Land-based



$3.6 B
(of $3.6 B)

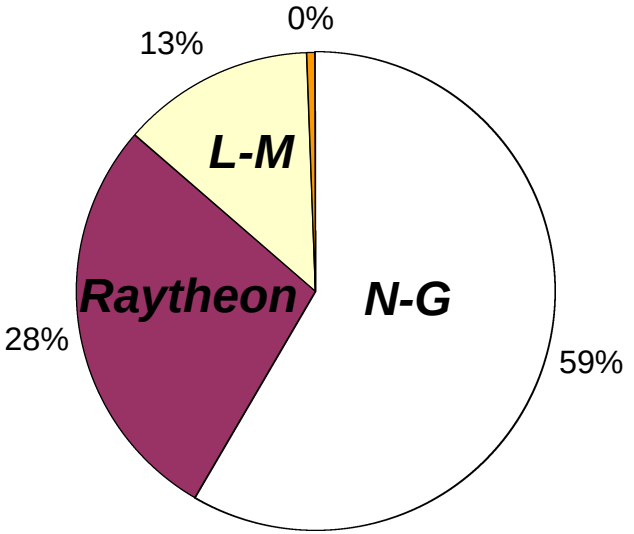
Shipborne



$1.1 B
(of $2.1 B)

- Northrop
- Raytheon
- Lockheed
- ITT
- Telephonics

Airborne



$2.6 B
(of $4.9 B)

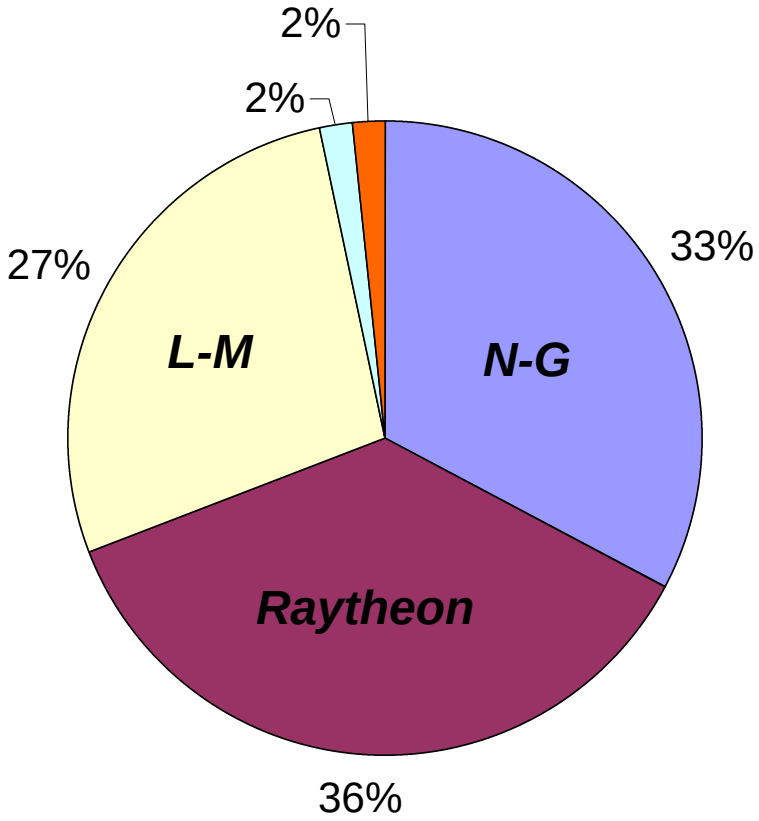
Total Market = $10.6 B
($7.3 B awarded)

Source:
DoD & DACIS

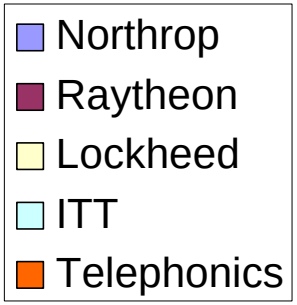
Radar Industrial Base

Total Market Share by Company (FY'00 - '07)

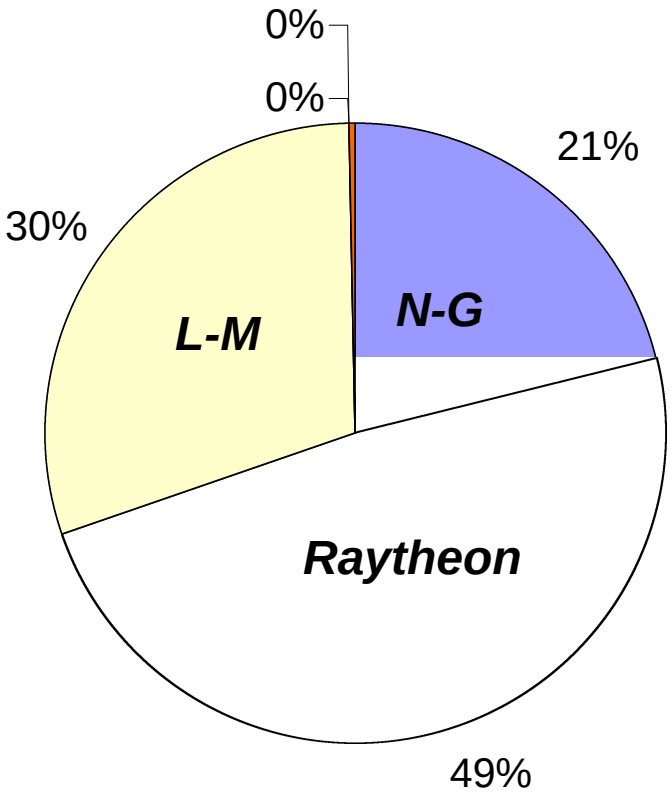
Production



Total Market = $18.3 B



R & D



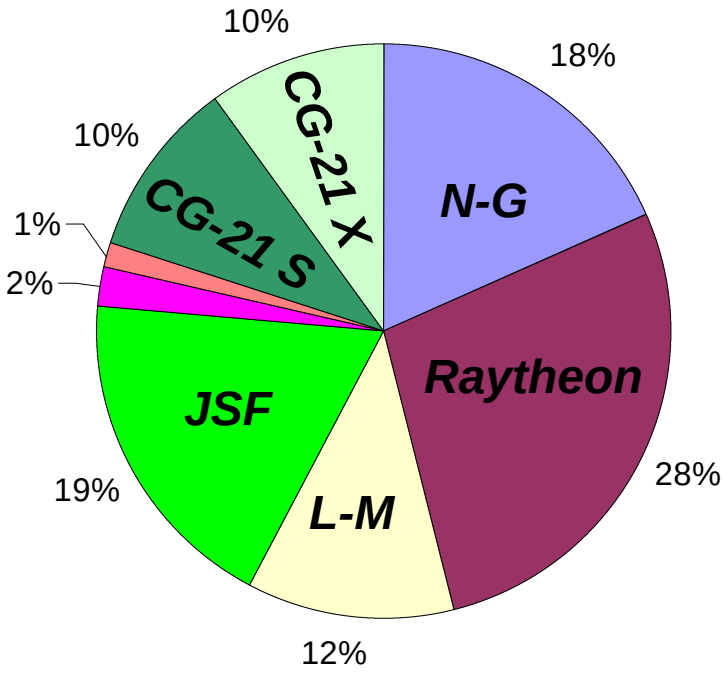
Total Market = $7.3 B

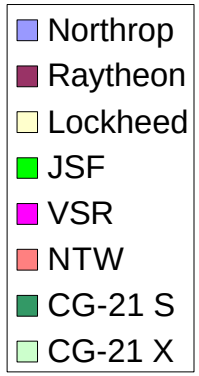
Source: Industry, DoD & DACIS

Radar Industrial Base

Total AESA Market (FY'00 - '30)

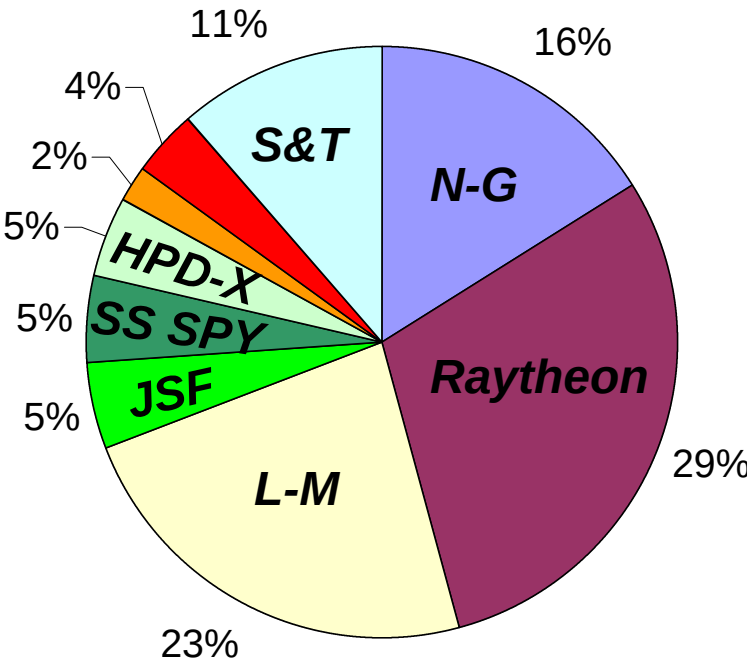
Production

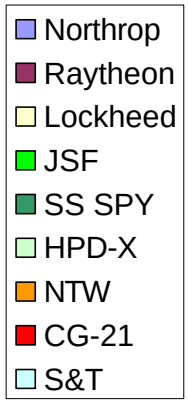




Total Market = $24.1 B

R&D





Total Market = $10.2 B

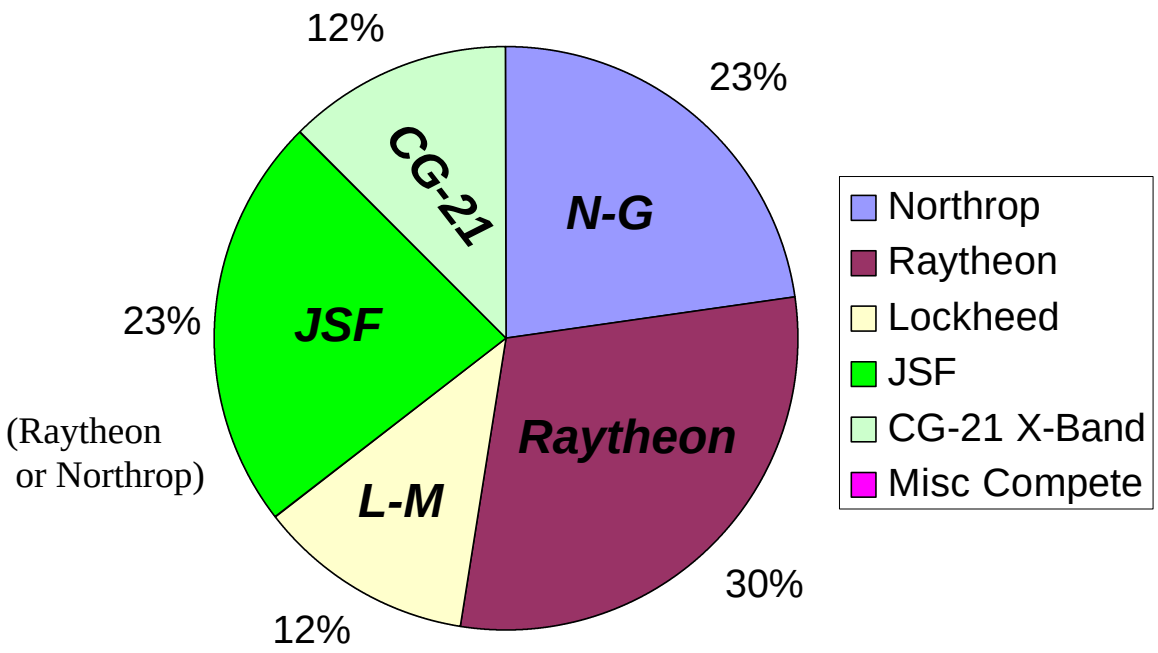
Note: This and the following slide use data through FY'30.
Data extending beyond the original '00-'07 set becomes sparse.

Source: Industry, DoD & DACIS

Radar Industrial Base

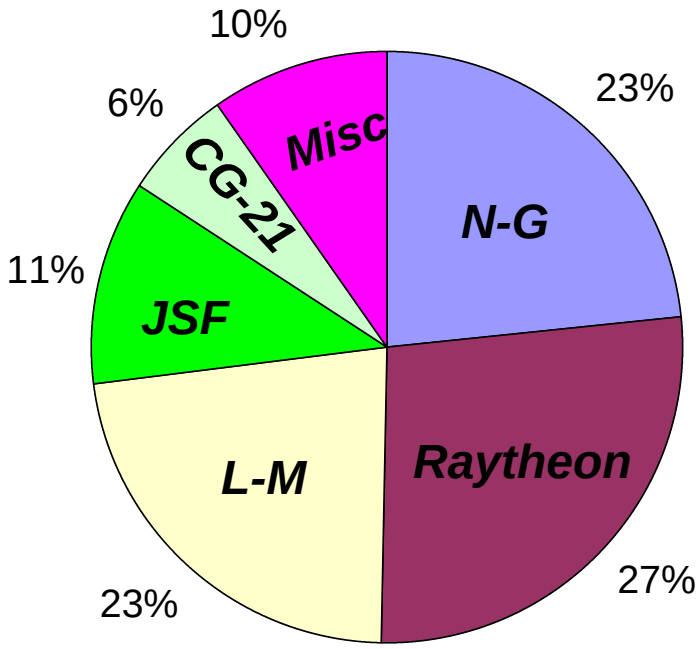
X-Band AESA vs Total Radar Production Base (FY'00 - 30)

X-Band AESA Radar



Total Market = $19.5 B

Total Radar



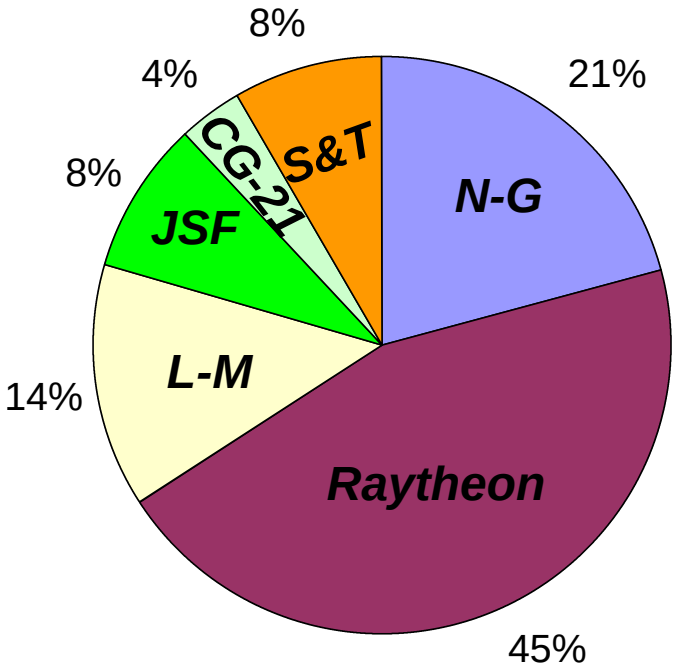
Total Market = $40.3 B

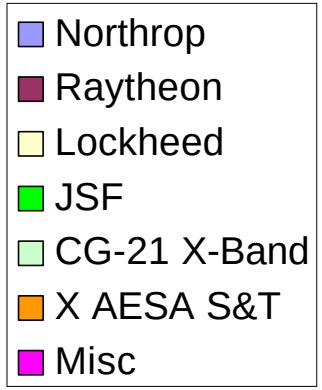
Source: Industry, DoD & DACIS

Radar Industrial Base

X-Band AESA vs Total Radar R&D Base (FY'00 - '07)

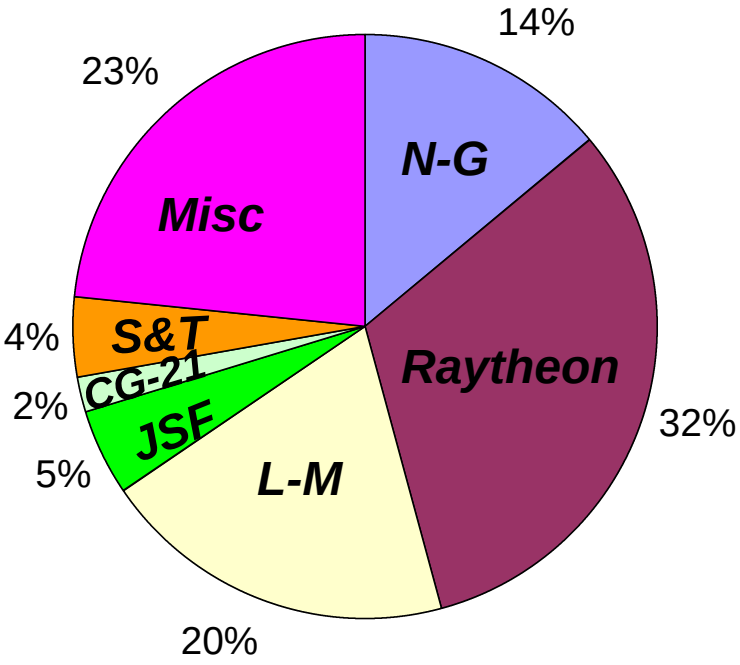
X-Band AESA Radar





Total Market = $5.9 B

Total Radar



Total Market = $11.1 B

Source: Industry, DoD & DACIS

Radar Industrial Base

Key Capabilities and Skills

Radar Industrial Base

Radar Key Capabilities

Capability	Hardware	Software	Integration
Hardware Design & Fabrication			
Active Array Technology			
Environmental Packaging & Constraints			
Signature Control			
Electronic Protection			
Discrimination Methods			
Multi Function Scheduling & Control			
Surface Mapping & Targeting			
Air Target Processing			
Subsystem Integration			
Platform Integration			
Weapon / Combat System Integration			

Radar Industrial Base

High/Low Band Partitioning

Low Band (<= S Band)

Typical Characteristics:

- System
  - Low precision
  - Surveillance/ target acquisition
- Production methods
  - Low technology
  - No clean room required
  - Discrete components
  - Manual assembly
  - Reflow solder attachment on simple printed circuit board

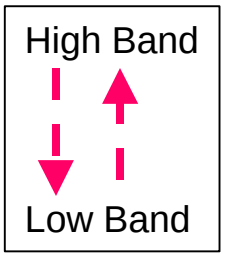
High Band (>= S Band)

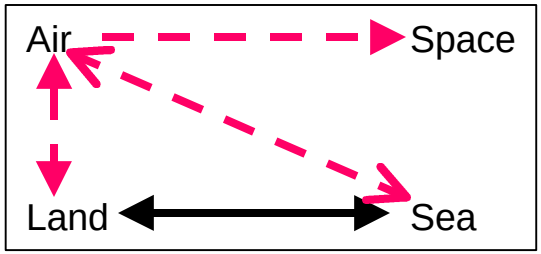
Typical Characteristics:

- System
  - High precision
  - Multiple simultaneous functions
- Production methods
  - High technology
  - Clean room required
  - MMIC components
  - Automated precision manufacture
  - Robotic attachment to high density multi-layer interconnect substrate

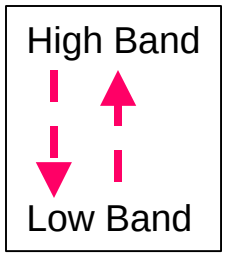
Radar functions and manufacturing processes provide a natural frequency partition.

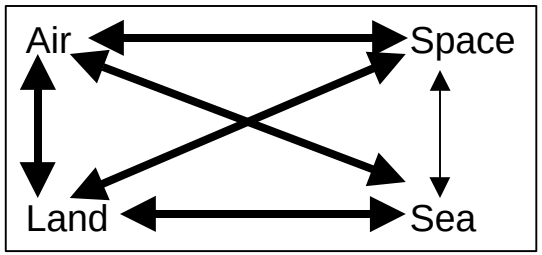
Inter-Platform Mapping Hardware



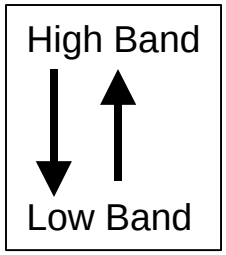


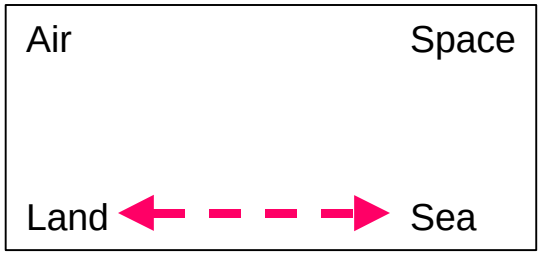
- Hardware Design and Fabrication
  - Low noise, low phase noise transmit and receive subsystems; efficient, high power
  - Direct digital synthesis and sampling
  - Wide bandwidth, large dynamic range processing
  - Radar structures for mechanical, electrical, power, and cooling performance





- Active Array Technology
  - T/R Modules
  - Module components (MMICs, Circulators, Interconnects, etc.
  - Subarray/array design, fab, and calibration

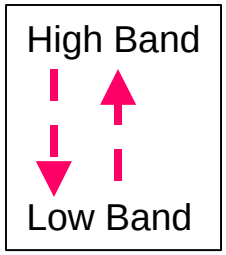


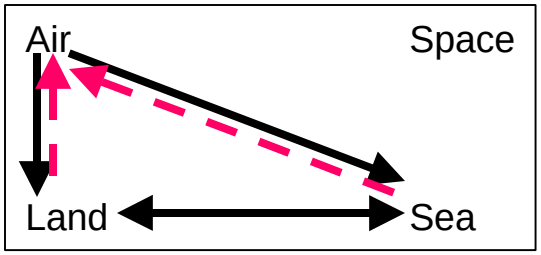


- Environmental Packaging and Constraints
  - Physical constraints
  - Weight, power, and cooling
  - Sand, salt spray, temperature extremes, etc

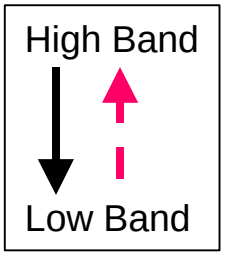
Strong link carries over intact. (→)
Weak link carries over somewhat. (⇢)
No link implies no carryover

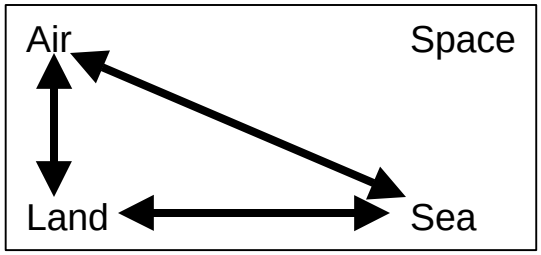
Inter-Platform Mapping Hardware/Software



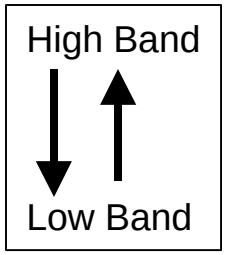


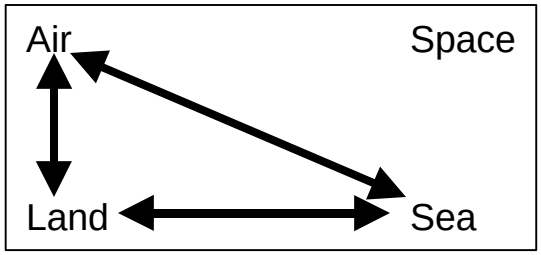
- Signature Control
  - Low observables technology design, fabrication, and integration
  - Low probability of intercept waveforms
  - Radar / radome / platform structure integration for signature control





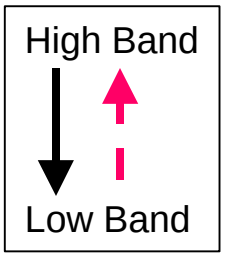
- Electronic Protection
  - ECCM measures: Adaptive beam nulling, sidelobe suppression/blanking, moving target indication, clutter suppression, etc.
  - Electronic support measures: External signal detection, classification, and direction finding

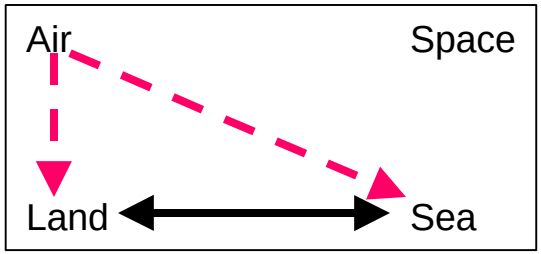




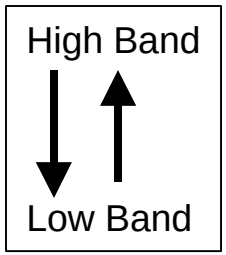
- Discrimination Methods
  - Automatic target recognition
  - High resolution for aimpoint selection
  - Debris / decoy discrimination

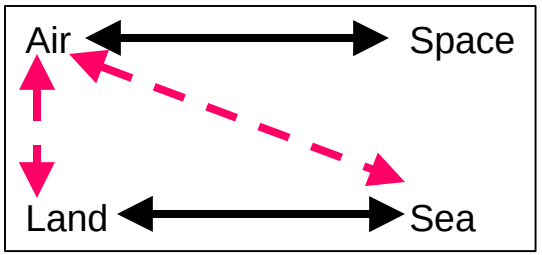
Inter-Platform Mapping Software



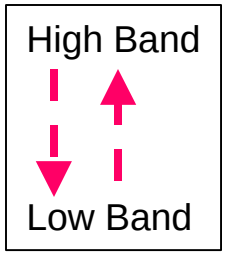


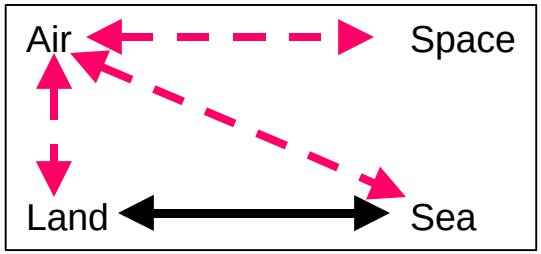
- Multi-Function Scheduling and Control
  - Adaptive search, track, engagement control
  - Interleaved air search/track and ground mapping
  - Special functions: Terrain following, precision approach control, missile midcourse guidance command, etc
  - Complex waveform generation





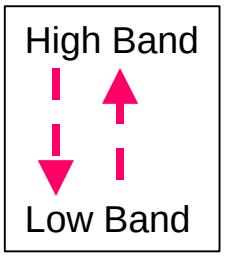
- Surface Mapping and Targeting
  - Surface mapping techniques: SAR, ISAR, GMTI
    - Real time automatic targeting
  - Detection and tracking methods
  - Navigation, terrain following

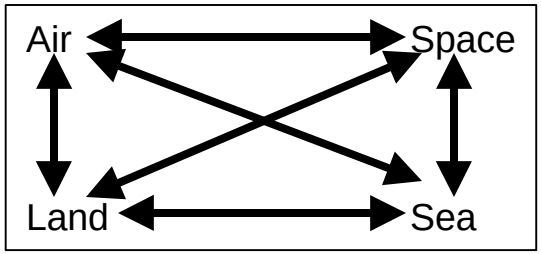




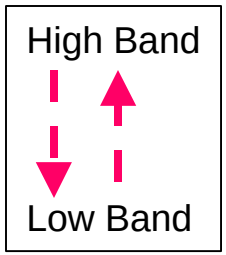
- Air Target Processing
  - Target / clutter separation
  - Space time adaptive processing
  - Waveform shaping / softening
  - Coherent & non-coherent integration
  - High resolution processing techniques

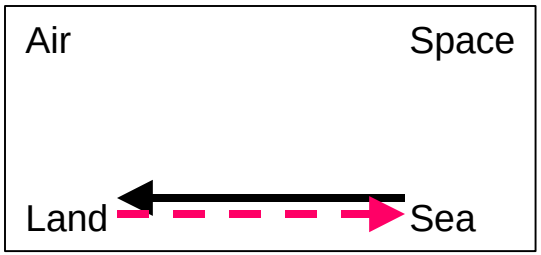
Inter-Platform Mapping Integration



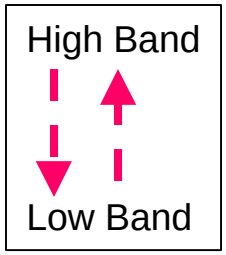


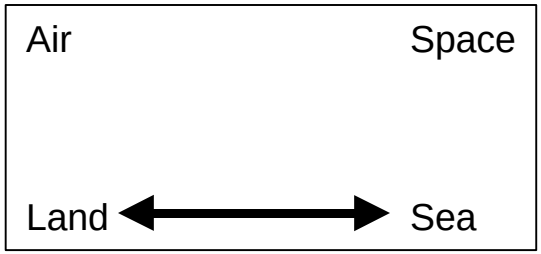
- Subsystem Integration and Test
  - Integration of transmitter, receiver, antenna, antenna control, processor, software into a system





- Platform Integration
  - Integration of radar into platform structure for proper mechanical, electrical, cooling, and signature fit and performance.





- Weapon / Combat System Integration
  - Physical, electrical, and data interface with interceptor systems and information systems of the host platform.

Radar Industrial Base

Radar Prime Involvement in Lower Tier Supply Chain

2nd Tier

- *Radomes*
- *Antennas*
- Transmitter Tubes
- ***T/R Modules***
- ***Receiver / Exciters***
- Processors
- *Power Supplies*
- *Power Converters*
- A/D, D/A Converters

3rd Tier

- *MMICs*
- Power Transistors
- *Circulators*
- ***Interconnect / Substrates***
- Module Casings
- AlSiC moldings
- Optoelectronic Amplifiers
- *SAW Devices*
- ASICs
- *Oscillators*
- Phase Shifters

4th Tier

- Semiconductor wafers
- Oscillator crystals
- Waveguide
- Connectors
- Cabling, electric & optical
- Discrete electronic components
- Solder, epoxy, etc.
- Programming Languages
- Software Development Tools
- CAD/CAM Software

Xx: ***Radar prime in-house***
Xx: Merchant supplier
Xx: ***Both***

Primes typically fabricate in-house those items which are discriminants or which are not available from merchant suppliers.

Radar Industrial Base

Open Architecture & Competition

- History of upgrades and modifications
  - Usually awarded to incumbent as the only source with the system knowledge
  - Most common are signal/data processing upgrades; next are receiver/exciter improvements
- Open architecture facilitates competition in upgrades
  - Isolates elements to be upgraded from the rest of the radar
  - Removes proprietary barriers otherwise unrelated to the upgrade
- Open architecture requires:
  - Modular, loosely coupled architecture
  - Well defined publicly available interface formats
    - Best suited to digital elements, so is becoming more practical as radar evolves from analog to digital componentry
- JSF is pursuing radar open architecture to facilitate upgrades and parts obsolescence control

Radar Industrial Base

Findings and Conclusions

- **AESA** is becoming the military radar standard
  - **Increased commonality** of the tech base across platforms (land, sea, air)
- **Demand is robust**
  - **Sufficient** demand exists to sustain **three major competitors**
- The **market is more equitably distributed** than contractor expressed concerns would suggest
  - **No specific DoD actions** are required today to maintain sufficient capability and competition
  - Procurement and R&D funding spread across companies is sufficient to adequately maintain key capabilities for each platform type at two or more companies
- Intra-company rationalization of the radar industrial base is warranted
- DoD should **require incorporation of open architecture** in future radar designs to facilitate upgrades for performance and obsolescence, and open them to competition

DoD should monitor radar market; update study in '02